Chapter IV.—A REPORT ON THE ALGÆ OF SPINDLE ROCKS, WOODS HOLE HARBOR.

That many algæ have well-defined seasons of vegetative growth is well known, but there have been very few detailed or intensive studies of particular regions covering sufficiently long periods to give important conclusions. It is certain, however, that there are seasonal floras which follow one another over the same area in much the same manner as terrestrial floras. This study was undertaken in the hope that observations on a particular group of rocks at Woods Hole at various seasons might bring out some important facts on the life habits of the algæ of this region.

The rocks selected for the study seemed particularly well adapted for the purpose. They were a group of bowlders called by the writer Spindle Rocks because, lying off Grassy Ledge at the entrance to the ship channel in the passage of Woods Hole, they bore a light on an iron spindle. Unfortunately for the continuation of the work, the rocks were removed during the summer of 1906 by dredging operations of the Government to widen the ship channel, and the spindle was shifted to another position.

The destruction of the old group of rocks of course ended the observations, which had been in progress for 15 months, beginning in the summer of 1904 and extending through the summer of 1905. The studies over this period, however, are of considerable interest, since they cover the seasonal changes of one entire year. They are illustrated by 8 charts, which are selected from a series of 10 made during this period.

Spindle Rocks, as shown on the charts (267–274), was a group of 10 bowlders, the smallest having a length of about 5 feet and the largest of about 9½ feet. Some portion of each rock was exposed at low water and all of the rocks were covered at high tide. The rocks lay to the north or right of the entrance to the ship channel leading through the passage from Woods Hole Harbor to Buzzards Bay and were an outlying portion of Grassy Ledge. The rocks were exposed to very swift tide currents, which flow through the channel at a rate of 5 to 8 miles an hour. The ledge fell off abruptly on all sides, but between the rocks the depth was 1 to 6 feet. The outlines of the bowlders were plotted in a chart showing their form and position as viewed from above. The low-water mark was sketched for each rock by a dotted line, and above it two other lines indicating tide marks 2 and 5 inches, respectively, above low water. A plate was made from the original drawing and charts were printed to be used for making the records. In the work of preparing this chart the writer received much assistance from Mr. F. W. Cushwa.

The study was concerned entirely with the flora over the tops of the rocks and below low-water mark to a depth of 3 to 6 feet. Each species was given a number, and charts were plotted at intervals, the numbers with accompanying notes showing the position and abundance of the algæ over the rocks. It was found most convenient in practice for two persons to take the record of the ledge, one making the examination and the other recording by number on the printed chart the position of each species. At the end of the study the list of species was arranged in the order adopted in the Catalogue,

necessitating a new set of numbers, which were substituted for the old. In all, 50 species were recorded on the rocks during the 15 months' study, the list being as follows:

List of algæ found on Spindle Rocks.

CYANOPHYCEÆ.

1. Calothrix scopulorum.
2. Rivularia atra.

CHLOROPHYCEÆ.

3. Ulothrix implexa.
4. Ulva Lactuca.
5. Ulva Lactuca var. rigida.
6. Enteromorpha crinita.
7. Enteromorpha intestinalis.
8. Enteromorpha prolifera.
9. Cladophora gracilis.
10. Cladophora lanosa.
11. Chadophora lanosa var. uncialis.
12. Codiolum gregarium.

PHÆOPHYCEÆ.

13. Ectocarpus æcidioides.
14. Ectocarpus confervoides.
15. Ectocarpus fasciculatus.
16. Ectocarpus granulosus.
17. Ectocarpus ovatus.
18. Ectocarpus penicillatus.
19. Ectocarpus siliculosus.
20. Ectocarpus tomentosus.
21. Sorocarpus uvæformis.
22. Desmotrichum balticum.
23. Desmotrichum undulatum.
24. Phyllitis fascia.
25. Punctaria plantaginea.
26. Scytosiphon lomentarius.
27. Desmarestia viridis.
28. Chordaria flagelliformis.
29. Mesogloia divaricata.
30. Myrionema corunnæ.
31. Chorda filum.
32. Chorda tomentosa.
33. Laminaria Agardhii.
34. Laminaria Agardhii var. vittata.
35. Fucus vesiculosus.
36. Sargassum Filipendula.

RHODOPHYCEÆ.

37. Porphyra laciniata.
38. Acrochætium secundatum.
39. Acrochætium virgatulum.
40. Nemalion multifidum.
41. Callithamnion Baileyi.
42. Callithamnion corymbosum.
43. Ceramium rubrum.
44. Chondria dasyphylla.
45. Dasya elegans.
46. Polysiphonia fibrillosa.
47. Polysiphonia urceolata.
48. Polysiphonia violacea.
49. Chondrus crispus.
50. Champia parvula.

The detailed records of the accompanying eight charts (no. 267–274) have been given in the legends, and it is only necessary in this account to present the most important conclusions from the study of the rocks throughout the seasons.

During the winter the tops of the rocks were scraped perfectly bare of vegetation, and even of barnacles, by the floating ice carried back and forth through the channel by the swft tides.[a] The conditions at the end of the winter of 1905 are shown in chart 267, recorded March 17, 1905. It is interesting to compare this chart with chart 274, of December 30, 1904, which shows algæ well distributed over the upper portion of almost every rock. That vegetation had been entirely swept away in the two and one-half months elapsing between the two records, and no algæ had as yet formed a perceptible new growth. This history is probably that of every bowlder along the shore

[a] There are, however, winters at Woods Hole when practically no floating ice is present, and at such times the algæ are not affected.

when exposed to similar ice scraping and shows clearly why the littoral flora in mid-winter is so little developed in this region. Returning to chart 267, it will be seen that the algæ were all below low-water mark, the most conspicuous forms being *Ceramium rubrum* (43) and *Chondrus crispus* (49), forming a zone around the rocks.

The group of rocks a month later presented a very different aspect, as shown in chart 268, recorded on April 22. *Cladophora lanosa* var. *uncialis* (11) had appeared in considerable quantity near low-water mark, and somewhat lower down was an imperfect zone consisting of young growth of *Phyllitis fascia* (24) and *Scytosiphon lomentarius* (26). *Polysiphonia urceolata* (47) had appeared well below low-water mark and was the most conspicuous member of a zone of red algæ, including *Ceramium rubrum* (43) and *Chondrus crispus* (49). There were present *Sorocarpus uvæformis*, four species of *Ectocarpus*, and the two species of *Desmotrichum*, all new to the rocks, showing how quickly such algæ, reproducing by zoospores, may establish themselves. A notably new form was *Chorda tomentosa* (32), which had begun to appear.

Chart 269, recorded May 22, shows the conditions after another month, and when the spring flora was at its full development. *Cladophora lanosa* var. *uncialis* (11) was still the dominant green alga, but *Enteromorpha intestinalis* (7) had begun to appear, and these two algæ had extended the green zone much higher on the rocks than at the previous date, April 22 (chart 268). The brown zone at low-water mark, composed chiefly of *Ectocarpus penicillatus* (18), *Phyllitis fascia* (24), *Scytosiphon lomentarius* (26), and *Chordaria flagelliformis* (28), was much more evident. *Polysiphonia urceolata* (47) was very conspicuous in the zone of red algæ below the brown. *Chorda tomentosa* (32) was abundant.

Conditions were very greatly changed after another month, as shown in chart 270, recorded June 29, the spring flora having given place to the beginning of the summer flora. *Cladophora lanosa* var. *uncialis* had entirely disappeared, and the prominent green zone above low-water mark was composed of *Ulothrix implexa* (3) and *Enteromorpha intestinalis* (7), with young growths of *Ulva Lactuca* var. *rigida* (5). The brown zone near low-water mark was now chiefly *Scytosiphon lomentarius* (26) and *Chordaria flagelliformis* (28); *Phyllitis fascia* was represented by only a few old plants and *Ectocarpus penicillatus* had disappeared. The other species of *Ectocarpus*, *Desmotrichum*, and *Sorocarpus uvæformis*, as well as *Chorda tomentosa*, were also no longer present. *Polysiphonia urceolata* had disappeared, its place being taken by *Polysiphonia violacea* (48), which with *Ceramium rubrum* (43) and *Chondrus crispus* (49) chiefly composed the zone of red algæ below the brown zone. *Nemalion multifidum* (40), a characteristic summer species, had begun to appear at and above low-water mark.

The typical summer flora is shown on chart 271, recorded July 22. The conspicuous green alga was *Ulva Lactuca* var. *rigida* (5), growing in large patches with other green algæ in small quantities. There was a well-defined brown zone just above low water composed chiefly of *Chordaria flagelliformis* (28) and *Scytosiphon lomentarius* (26), both bearing *Ectocarpus confervoides* (14) as a conspicuous epiphyte; *Phyllitis fascia* had disappeared. *Nemalion multifidum* (40) was now plentiful, fringing the rocks at low-water mark. Below the brown zone and mixed with it were abundant growths of *Ceramium rubrum* (43), *Polysiphonia violacea* (48), and *Chondrus crispus* (49). Chart 272, recorded September 2, is similar to chart 271, but with certain features more pronounced. The most

prominent zone (much more conspicuous than in chart 271) was just below low water and composed of *Ceramium rubrum* (43) and *Polysiphonia violacea* (48), these two forms having taken the region formerly occupied by the brown zone. Chart 273, recorded September 19, 1904, a year previous to the last, is interesting because there was no *Chordaria flagelliformis* that season and very little *Polysiphonia violacea*, but an abundance of *Polysiphonia fibrillosa* (46), which took the place of the first two species, forming with *Ceramium rubrum* (43) a dense zone below low-water mark.

The conditions at the beginning of the winter and before the rocks were scraped by floating ice are shown in chart 274, recorded December 30, 1904. This chart in the sequence follows chart 273, of September 19, 1904, and precedes chart 267, of March 17, 1905, by two and one-half months. The prevailing green alga was *Cladophora lanosa* var. *uncialis* (11), which had taken the place of *Ulva Lactuca* var. *rigida* (5), so abundant in the summer, but now only represented by the bases of old plants. The brown zone was composed of *Phyllitis fascia* (24) and *Scytosiphon lomentarius* (26); there was no *Chordaria flagelliformis*. *Ceramium rubrum* (43) was abundant below the brown zone but *Polysiphonia fibrillosa* (46) had almost disappeared. Two species of *Ectocarpus* were present, together with several other epiphytic brown and red algæ.

A close study of this series of charts will show very graphically the general nature and extent of the seasonal changes that must take place on very many ledges and groups of rocks along the coast, and similar seasonal changes would be expected wherever there is a well-developed littoral and sublittoral flora near low-water mark. Intensive studies of this character of well-chosen situations are far more important for our knowledge of seasonal habits and algal successions than random collecting undertaken along the shore. It is much to be desired that such work be systematically undertaken by those in a position to make detailed records over extended periods. Perhaps this brief record of a study (abruptly terminated by the destruction of the selected station), which shows such interesting results, will lead others to make similar investigations.

In conclusion we wish to acknowledge our indebtedness to Miss Lillian J. MacRae, who, with the assistance of Mr. Collins, made the records of several charts at seasons when it was impossible for us to be at Woods Hole.